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OBSERVATIONS ON POPULATIONS OF ADULT BEAVER-BEETLES, PLATYPSYLLUS CASTORIS

(Platypsyllidae: Coleoptera)

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INTRODUCTION

While trapping beaver in the Mississippi River bottom-lands below Hastings, Minnesota in March, 1960, many of the two-year-olds were found to be heavily infested with the coleopterous ectoparasite, *Platypsyllus castoris* Ritsema. Since the beaver taken in previous years were old, mature beaver and did not have a heavy infestation, it was suspected that the beetles were segregating out on the two-year-olds. It was suggested that this could be a mechanism to insure infestation of the new colonies that would be established by the young beaver. If this segregation really existed, it was hypothesized that sampling of the population during the winter (when the beaver are icebound), and then during the spring (at the beginning of dispersal), would show differences in beetle densities per beaver that would be correlated with the age of the beaver and with the time of sampling. On this basis, two samples were taken; one during the December-January period (1960-1961) and the other during the late March and early April legal trapping season (1961). It was hoped that both samples would be similar in size and representation of colonies, but the spring work was partially interrupted by the activities of local fur trappers.

The previous published investigations dealing with *P. castoris* have been primarily of two types: taxonomic (Ritsema, 1869; Riley, 1892) and parasite surveys concomitant with investigations of beaver biology (Lawrence, Hays & Graham, 1961; Erickson, 1944; Parks & Barnes, 1955). Essentially no consideration has been given to parasite populations per beaver and there appears to be a complete lack of discussion of the behavior of the beetle. There appear to be some differences in the life history of the beetle between the Michigan Upper Peninsula (Lawrence, Hays & Graham, 1961) and the area below Hastings. Despite the fact that no evidence was gathered in support of differential infestation of beaver age-classes, it seems advisable to report the observations made on the beaver-parasite relationship and beetle behavior.

The author would like to express extreme gratitude to Dr. William Schmid of the Department of Biology, University of North Dakota, for his untiring labor in helping to set traps and to process the beaver. In the short time that was available for this study, the winter sample would not have been possible without the much appreciated loan of a dozen "Conibear" beaver traps by Mr. Don Gray of the Upper Mississippi Federal Wildlife Refuge. The author is deeply indebted to Dr. R. F. Smith, Department of Entomology and Parasitology, University of California, Berkeley, for reading the manuscript and offering a multitude of suggestions.

Methods

Study area: In those publications which deal with *P. castoris*, there has been little or no description of the area and circumstances under which the beaver were taken. This makes comparisons difficult and to avoid this a general description of the area is included.

The study area is a flood plain on the west side of the Mississippi River, between 10 and 15 miles south of Hastings, Minnesota. The action of spring floods has divided it into shallow lakes, marshes, and channels. The lakes have *Salix* and *Carex* borders, the marshes have dense stands of *Salix, Alnus, Carex, Scirpus fluviatilis*, and *Phragmites communis*, and the channels, while in general free of plant growth, pass through sand ridges which are covered with older *Salix* thickets, *Acer saccharinum, Populus deltoides, Acer negundo*, and *Ostrya virginiana*.

The area varies in width from one to two miles. To the west, it is restricted by rising farmland with streams which occasionally harbor beaver colonies. To the east, it is bounded by the main channel of the river which is in turn bounded by high limestone cliffs. The boundaries of the smaller water bodies within the area change from year to year because of fluctuating water levels. In the winter, the waters which are not directly connected to the main river current have six to fifteen inches of ice which restricts the beaver to their lodge area. Beaver which construct their lodges on the banks of the main river or at the mouths of channels which have strong current flow are normally not ice-bound during the winter and are known to range at least 200 yards from the lodge.

This area was chosen because of its high beaver population, relative isolation from other colonies, and familiarity to the author. During the course of the study all of the colonies in the area were discovered.

Since the spring samples were incomplete, it was also necessary to sample an old colony which was located in a very similar environment, four miles south of St. Paul, Minnesota, and an area two miles south of Coon Rapids, Minnesota. Both localities are on the Mississippi River. A few beaver were taken in each of these places. Any data presented that were taken from these animals will be so designated.

Beaver colony structure and movements: Two of the lodges in the area were in open water, built up from the bottom mud (No's. 6,9) and in shallower water than is the case with pond beaver. The other ten were bank dens in sandy silt or mudbanks. Winter food caches were established at all of the lodges but at those bank dens where there was open water, winter foraging over the snow was frequent, even though large food stocks were still present. Four of the lodges were built during the summer of 1960 (No's. 5,6,9,11). The other lodges were two or more years old. Some were very old as indicated by the number of times they had been rebuilt and the number of adjacent collapsed bank dens. The most common terrestrial foods were *Salix, Populus, Acer saccharinum,* and *Alnus*.

When the spring thaw occurs, the beaver in this area are subject to a disturbance which most non-river beaver do not experience; they are flooded out of their lodges. For a period of two to six weeks, the water varies from a depth about two feet below the top of the lodge to a depth of four to six feet over the top. This does not seem to disturb the beaver, as during the March and April season, a family could always be found within 250 yards of the flooded lodges that had been occupied during the winter months. Flooding does not prevent later use of the lodge, as many of them have been in use for several years. However, this inundation may well influence other occupants of the beaver lodge by the action of the water, effects of the layers of silt left by receding waters, and the temporary absence of the beaver.

It is generally accepted among mammalogists and trappers that the two-year-old beaver of a colony leave in the spring and wander widely. Apparently most of the crop of young beaver from this area pass up or down river to build new lodges, as almost every bay and channel in this study area has a lodge or the remains of one. A further indication that it is primarily the young which disperse in the early spring is that all the sixteen beaver caught by my wife and me in 1960, more than 500 yards from a lodge were two-year-olds. This represented 16/17 of the beaver that had disturbed the sets.

Trapping conditions: Between December 20, 1960 and January 4, 1961 the author and Dr. Schmid tried to take a sample representing both sexes and/or several age classes from each colony. Conibear traps were set by hanging them through holes cut in the ice over the deepest water in the vicnity of the lodge. They were baited with bundles of poplar twigs, but since the twigs were never eaten even in sprung traps, it is possible that the beaver swam through the traps by accident or curiosity. One young beaver was caught by the hind leg, rather than the usual head or chest hold. The beaver were drowned and their body heat often melted them into the ice, which then froze again. In these cases, the back muscles and hide were frozen hard. Apparently this did not greatly affect the beetles, because if one placed his warm hand against this frozen area, immediately there were active beetles crawling up out of the fur. The traps were examined every day or every two days. When taken from the traps, some beaver were still warm while others were in various stages of freezing. Twenty beaver were taken in this manner.

The beaver were laid on snow and skinned immediately. Every effort was made to keep the warmth of the skinner's body from reaching the beaver as the beetles are very responsive to warmth. Each hide was placed separately in a plastic bag with a card giving locality, date, sex, girth, length, approximate weight, and other ecological notes. At no time did one beaver come in contact with another after being removed from the trap. It was because of the definite possibility of contamination of one beaver by another that the beaver trapped by local trappers could not be used. The pelts were stored in snow and later placed in a refrigerator. No mention has been made in the published literature of precautions taken to avoid cross-contamination where more than one animal was involved.

In March and April, the area was entered by canoe and the beaver were taken in conventional steel traps, set in shallow water using a suspension of the castor gland as an attractant. Apparently, the use of this lure does not cause sample bias as the experience of fellow trappers and myself has been that all ages and both sexes come to castor scent piles. Drowning sets were made but due to water fluctuations and bad luck, only about half of the animals caught were drowned. Those still alive were dispatched and like the drowned beaver, were treated in the same manner as those taken in the winter period. However, in several cases, the entire beaver was placed in a plastic freezer bag and transported to a more convenient working place.

Age determinations were made on the basis of three size clusters which have appeared in every group of beaver that the author has trapped in Minnesota; the smallest are one year old, the next two years old, and the next three or over. These three are quite distinct and the last group occasionally has members which on the basis of their weight and length, are probably five years or older in age. The beaver were sexed by dissection and at this time of year, testes are easily distinguishable from castor glands. The beaver were considered as having been taken in the colony when caught within 50 yards of the lodge and were considered to be wanderers when taken further than 400 yards from a lodge or bank den; traps were set only in these ranges.

Observations on Live Platypsyllus

Removing and counting the beetles: In the published investigations concerning *P. castoris*, the beetles presumably have been obtained by superficial examination of a dead or live beaver. Lawrence, Hays & Graham (1961) combed anesthesized and drowned beaver for all types of ectoparasites and apparently felt that they were obtaining a representative sample. In the present investigation, when the cold hide was taken from the refrigerator, the beetles responded to the presence of warm air and within 30 seconds many were found crawling over the guard hairs on all parts of the pelt. If the skin was flat on a table top, they remained dispersed, but if it was hung by one end, the beetles immediately moved upward and congregated at the uppermost end. All of the visible beetles were placed in alcohol or in vials with a bit of wet fur, which was then placed in the refrigerator (2° - 4° C.) for future experiments. The pelt was then combed with a fine toothed flea comb in an attempt to determine how many beetles were not responding to the heat stimulus. In three cases, no extra beetles were found; in the other 35, from 1 to 16 live beetles were found. The number of unresponsive individuals per beaver increased as the total number of beetles per beaver increased. In all of the combing, only four dead beetles and no larvae, eggs or pupae were found. These pelts had been in the refrigerator for one to three days. Beaver pelts with high populations of beetles had from six to 20 dead (drowned?) beetles in the water in the bottom of their plastic sacks.

All of the beaver pelts taken outside the regular trapping season were cut into strips and dissolved in KOH to extract additional beetles and any other arthopods present. The debris from this maceration was examined with a binocular microscope and the other arthropods noted. No eggs, larvae, or pupae of *P. castoris* and from 0 to 11 adult beetles per pelt were recovered (mean 2.2). The hair mite *Schizocarpus mingaudi* Trouessant was occasionally present in the hair combings and was found in large numbers (100 plus per beaver) on the lysed beaved pelts. Since this hair mite was combed from all parts of the body, it was considered to be a generally distributed ectoparasite. The hair mite *Prolabidocarpus canadensis* Lawrence was found only on the head when combing, and most commonly as clusters of 50-1000 individuals on the fine hair just inside the forward edge of the ear opening. They were stacked 5-10 deep per hair and every beaver examined had a cluster in one or both ears. No ticks, lice, fleas or other Coleoptera were presnt in combings or lysed pelts. Since the beaver taken during the regular trapping season were only combed, their beetle populations should not be taken as exact, but they probably can be considered to be within five per cent of the total number. The data are presented in table 1.

Beetle behavior: Characteristic activities by the beetles were noted while removing them from the cold skins. When the beetle senses heat, it crawls to the end of a guard hair, waves its front legs in the air, and often falls off. If it falls into the fur, it repeats the action. If it falls on its back on a flat surface, it can easily right itself. It will then crawl for about two hours at room temperature with occasional "rest" periods. Looking quite shriveled, it will cease movement during the third hour if not placed in a humid atmosphere. If the beetle falls into a cup of water, it always ends up on its back after a few seconds struggle. It then remains motionless until touched by an object or ripple, in which case it waves its legs very actively and will grasp the contacting object and crawl up it quickly. Those that were left in water were still plump and active after twelve hours.

The beetles are not always easy to capture while in the fur. If an exposed beetle is pinched with fingers or forceps, it burrows back into the underfur. The beetles are able to move very rapidly in the fur; this is a function of well developed legs, margins of many body and appendage sclerites heavily covered with posteriorly directed spines, and the dorso-ventral compression. The beetles can outrun a comb passing through a dense pelt. They are very responsive to disturbance in the fur and can move transversely across the pelt faster than one's fingers can follow.

Three hundred beetles preserved in alcohol had sex ratio of 1♂:1.3♀. They are easily sexed by observing the relatively large adeagus through the light brown integument. The gut contents of live specimens were examined and no hair fragments were found. The gut was packed with matter which upon removal and separation had the general facies of bits of epidermal tissue; i.e., flat and translucent particles, with irregular edges. No evidence of erythrocytes or mite parts was seen.

Resistance to temperature extremes and desiccation: Since ectoparasites are generally thought of as having narrow temperature and humidity tolerances, it seemed pertinent to determine what ranges were favorable for the beetles. Vials, each with 10 beetles and a tuft of underhair, were enclosed in jars with salt solutions producing relative humidities of 50, 75, 89, and 96 per cent at 36° C, and at 26° C. After 48 hours, there were no survivors at 36° C, and at 26° C with 50 and 75 per cent relative humidity. At 26° C and 89 and 96 per cent relative humidity, less than 50 per cent were dead after 48 hours (mean dead per vial = 4, S. D. = 2.4), and there was one beetle alive at 26° C, 89 per cent relative humidity, after 120 hours. Those beetles in the refrigerator at 4° C were living at a high relative humidity because there were drops of free water in the fur which did not evaporate. Two samples (312 and 102 beetles) at 4° C took at least 14 days to show 50 per cent mortality. Sixteen days after placing these vials in the refrigerator, some beetles still crawled about in the fur. The relationships indicated by these limited data is not surprising, since the beetles must survive relatively long periods of cold when the beaver is in the water or sitting on the ice. The fact that the beetles apparently could not tolerate temperature in the mammal body heat range, and that they are active in cold air (4° C) reflects the possibility that the steepest heat gradient across the beaver hide is from internal tissue to outer edge of epidermis rather than across the underfur layer which constitutes the beetle's environment. *A priori,* one might expect the underfur environment to be quite warm, as the water layer does not penetrate past the outer edge of the underfur. That the beetles are not resistant to desiccation is to be expected since the relative humidity in the underfur air spaces must be high.

An unsuccessful attempt was made to keep the beetles alive on laboratory white mice and guinea pigs. A mouse would ignore the beetle crawling on its skin (under the fur) for 10 to 60 seconds and then would turn as if bitten, grab, and eat the beetle. Sixteen live beetles were placed on the fur of the relatively defenseless guinea pig and the animal's cage placed over a catch

Table 1. Data on individual beaver and their beetle populations.

Colony Number	Sample: Winter=A Spring=B	Sex	Age in years	Beaver Live=A Dead=D	Lodge Age	Water Level	Number of Beetles	Combed=C Lysed=L
3	A	M	1	D	2 yr plus	Normal	104	L
	A	M	2	D		N	192	L
	A	M	2	D		N	142	L
	A	M	1	D		N	243	L
	A	F	1	D		N	47	L
	B	F	2	A		N	102	C
5	A	M	3+	D	1 yr	Drying	51	L
	A	F	3+	D		D	73	L
	A	M	1	D		D	41	L
	B	F	1	A		Dry	16	C
6	A	F	2	D	1 yr	N	7	L
	A	*F	3+	D		N	0	L
	B	F	2	D		D	5	C
7	A	F	2	D	2 yr plus	N	0	L
	A	F	3+	D		N	1	L
	A	M	2	D		N	0	L
	B	F	2	A		Dry	0	C

1	A	M	3+	D	1 yr	N	10	L
	A	F	3+	D		N	4	L
	A	M	2	D		N	1	L
	B	M	2	A		D	16	C
8	A	M	2	D	3 yr plus	N	0	L
	A	M	2	D		N	0	L
	B	F	1	D		D	10	C
4	A	*F	4+	D	3 yr plus	N	4	L
	A	M	2	D		N	76	L
W.	B	M	2	D		Flood	2	C
	B	M	2	D		Flood	82	L
	B	*F	4+	A		Flood	2	L
	B	F	3+	A		Flood	2	L
	B	M	2	A		Flood	14	L
	B	M	2	D		Flood	89	C
S.P.	B	M	3+	D		Flood	15	C
	B	*F	3+	D		Flood	83	C
	B	M	1	D		Normal	9	C
	B	M	2	D		Flood	3	C
C.R.	B	F	3+	A		Normal	9	C
	B	M	2	A		Normal	0	C

Legend:
* Pregnant
W. Wandering beaver more than 400 yards from any lodge or bank den
S.P. Beaver taken in the study area immediately below St. Paul, Minn.
C.R. Beaver taken in the study area immediately below Coon Rapids, Minn.

Colony Number
Sample:
Winter=A
Spring=B
Sex
Age in years
Beaver
Live=A
Dead=D
Lodge Age
Water Level
Number of Beetles
Combed=C
Lysed=L

pan. In the next three days, 13 of the beetles were found dead in the pan and the other three were not recovered by combing. Since the guinea pig lacks underfur, one would expect the relative humidity in the fur to be much lower than that of a beaver's. The beetles appear to have no inclination to leave a live beaver; one that was known to be infested with beetles was kept caged at room temperature for three days and no beetles were found in the pan under the cage.

Discussion

Platypsyllus: Riley (1892) has reported taking both larvae and adults from beaver fur. Lawrence, Hays & Graham (1961) found both of these stages in the fur throughout the entire year and express the view that the egg and pupal stages are passed in the lodge litter or walls, though they had no material evidence. Since no larvae were found on the Hastings area beaver either in winter or spring, there is the possibility of a biological difference between the two beetle populations considered to be conspecific. Lawrence, Hays & Graham (1961) report the probable food of the beetle to be lymph and skin secretions (and perhaps blood). They also report that the beetles cannot live on muskrats. In the present study, it appears that the beetle at least ingests loose epidermis, as was shown by examination of gut contents.

A number of general observations can be made and tentatively explained from the data presented in Table 1. The range of beetles per beaver is large. There are some colonies which are heavily infested (No's. 3,5) while others are not (No's. 6,7,1,8). The beetle populations per beaver vary much less among members of each colony than between the beaver of the entire sample taken as a whole. The beetle populations taken below St. Paul and Coon Rapids are not grossly different from those at Hastings. The beaver being drowned in the trap does not seem to influence the number of beetles on it, indicating that the beetles only leave a cooling animal in response to a warmer object. These observations are not surprising if we think of the entire beetle population as being represented by isolated units (the beaver lodges), some of which possess a more favorable environment for the immature stages than do others. The beetles in these lodges apparently infest the beaver in proportion to the amount of reproduction allowed by the environment and the lodges are periodically reinoculated by visiting host animals that have been infested in other lodges. Further, the range of the two-year-olds is very broad so that the total beetle population in a given set of lodges will not be so much a function of the possibility of beetles being carried into the area as of the favorability of the parasite environment. Since the beetles apparently will not leave a dead host except in response to warmth, water currents or crawling by the beetle is probably not instrumental in its dispersion. It should be noted that the spring sample is smaller than the winter sample, but this is taken into account in the statistical treatments and does not appear to influence the above general observations.

In addition, the following hypotheses were examined in a formal statistical manner: 1) that the bettle populations on female beaver are equal to the populations on male beaver (t=0.54, 36 d.f., not significant); 2) that the populations on one-year-old, two-year-old, and three-year-plus beaver are the same (variance not significantly different by Bartlett's test, F=0.16, 2.35 d.f., not significant); 3) that the populations on the wandering beaver are equal to those on the beaver taken at their lodges (t=0.14, 36 d.f., not significant); 4) that the populations on the winter caught beaver are equal to those on the spring caught beaver (t=0.68, 36 d.f., not significant); 5) that the mean numbers of beetles per beaver per colony are equal (F=7.05, 7,23 d.f., highly significant difference). Failure to reject the first three hypotheses with a very low statistic indicates that the beetles, at this time of year, do no favor any particular portion of the host population. That the fourth one is not rejected seems to indicate that either the bettles do not have an appreciable mortality rate during the period sampled (three months between samples) or else they are emerging during this period. This does not necessarily mean that eggs and larvae are also present.

The rejection of the fifth hypothesis is in support of the idea that the favorability of the lodge environment may determine the numbers of beetles that are present on the beaver in an area. If we compare the population means of each colony (Table 2) with the range of variation within each colony (Table 1), it appears that the particular lodge influences the number of beetles on a beaver. Duncan's Multiple Range test has been used to distinguish those means which are significantly different (Table 2). Those means connected by the underline cannot be distinguished from each other at the 95 per cent level of significance. While the possibility of genetically determined resistance of the individual beaver should not be excluded, the sample involved in this study is not large enough or sufficiently documented to test the hypothesis that the animal itself is unfit for the beetle.

Table 2. Significantly different mean number of beetles/beaver/colony.

Colony number	3	5	4	13	1	6	8	7
Mean beetles/beaver	138	45	40	27	8	4	3	.25

While their effect on beetle numbers can only be hypothesized, it seems relevant to mention some of the variables that exist in the environment in which the immature stages presumably are passed. During the spring floods (two to six weeks), when many of the lodges are submerged, and for about a month in late summer when the lodge entrances may be as high as five feet above the water level, the beaver do not occupy the lodges. Further, the flood water, being heavily laden with silt, will deposit a coat of mud over the interior of the lodge as it recedes. Those lodges off of large rivers are not so dramatically subject to this disturbance. The lodges may be constructed on a number of substrates such as mud, gravel, sand, and clay. The materials used as bedding will depend on those available to the beaver. The duration of occupancy of the lodges in terms of years will vary depending upon the mortality factors acting on the beaver (trappers, disease) and the materials out of which the lodge is constructed. It should be realized that in a given colony there may actually be several sleeping chambers in one lodge or bank den system; each of the above factors may influence each of these sleeping chambers to a varying degree.

Beaver are often observed combing their fur with the two split toenails of their hind feet. It is a leisurely activity and cannot be expected to remove many beetles. Since fur needs to be clean of oils and flotsam to be water repellent, it is undoubtedly done for cleaning. Bailey (1923) has arrived at this conclusion also. Further, I have never observed a beaver to undergo the characteristic searching or scratching for a biting ectoparasite; it appears that any abrading of the skin that may be done by the beetle does not bother the beaver.

While the beetles show characteristics that seem useful if a beetle becomes separated from its host (resistance to cold, ability and inclination to climb contacting objects from a water surface), no observations have been made of "lost" beetles in nature, nor is there any direct evidence that beaver-to-beaver transfer occurs except by host contact.

Other ectoparasites: It is interesting to note that while Lawrence, Hays and Graham (1961) list twelve possible arthropod ectoparasites of beaver, only three were found on the animals in this area. They found the hair mite *Prolabidocarpus canadensis* to be common on their beaver, yet found none of the hair mite *Schizocarpus mingaudi* which is abundant in the residue from the lysed beaver pelts. There is a definite possibility that they combed over these small and tight-clinging mites. While they found both *Ixodes banski* Bishopp and *Leptinillus validus* Horn to be common, these were completely lacking in the Hastings beaver. As both *I. banski* and *L. validus* were recovered by them from nest litter, there is the definite possibility that their absence in the Hastings area is a function of the frequent flooding. It would be interesting to examine those beaver in the Hastings area whose lodges are not flooded for the presence of these two arthropods. *L. validus* has been recorded from Minnesota (Parks & Barnes, 1955) and *I. banski* has been established to be a beaver ectoparasite in Northern Michigan and Western Ontario (Lawrence, Hays & Graham, 1961).

Conclusion: It is apparent that much work needs to be done with this ectoparatsite under many environmental conditions. One major problem is finding a way to legally procure representative samples of the host at all times of the year without depleting the population of beaver or aggravating the local trappers. Furthermore, the physical labor involved in trapping and handling the animals in their own environment is considerable.

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NOTES AND SYNONYMY OF SOME NEOTROPICAL SPHEX AND ISODONTIA DESCRIBED BY E. TASCHENBERG AND S. ROHWER

(Hymenoptera: Sphecidae)

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The following notes are based primarily on Taschenberg type material generously lent by J. O. Husing of the Zoologisches Institut, Martin-Luther-Universitat, Halle, East Germany. In addition, a recent visit to the United States National Museum allowed the author to examine the Rohwer types in that Institution. I am designating lectotypes for the following Taschenberg species: *Isodontia nigrocoerulea*, *Sphex argentinus* and *micans*.

ISODONTIA CYANIPENNIS (Fabricius)

Sphex cyanipennis Fabricius, 1793. Ent. Syst., 2:200 (Cayenne, French Guiana, type lost).

Sphex nigrocoerulea Taschenberg, 1869. Zeitsch. Ges. Naturw. Halle, 34:415 (Lectotype ♀ and paralectotype ♀, Venezuela, present designation).

Isodontia bipunctata Rohwer, 1913. Proc. U.S. Nat. Mus., 44:452 (holotype ♀, Canal Zone, Panama). *New synonymy.*

J. van der Vecht (1961) suggested that Fabricius' *cyanipennis* is the same species described by Taschenberg as *nigrocoerulea*. However, Richards (1937) described a metallic blue *Isodontia* from a male colected in British Guiana, which may be a synonym of *cyanipennis*. If Richards' description of *Isodontia bastiniana* is accurate his species is distinct from *nigrocoerulea*. Richards states that the holotype of *bastiniana* lacks the prominent transverse bands of pale ciliia found on the gastral sternites of *nigrocoerulea*. In addition, the flagellomeres of *bastiniana* do not possess the spicules found on the flagellomeres of *nigrocoerulea*. A possibility